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## **SYSTEM ARCHITECTURE OF SEMICONDUCTOR MANUFACTURING EQUIPMENT**

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### **BACKGROUND OF THE INVENTION**

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#### Field of the Invention

The present invention relates generally to the field of semiconductor manufacturing. More specifically, the present invention relates to system architecture of semiconductor manufacturing equipment for ultra high system throughput with reduced cost.

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#### Description of the Related Art

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Semiconductor substrates (wafers) typically have many layers deposited thereon for device fabrication. Depositing many layers of various films is typically performed

using deposition systems with multiple chambers designed for various processes. One of the most important performance indexes of the semiconductor manufacturing system is the system throughput, which is typically described as number of  
5 wafers per hour (wph). A single bottleneck point typically limits the system throughput, and this bottleneck can be a process chamber or a cluster robot (either a buffer robot or a transfer robot). If the chamber process times are short enough, the theoretical limit of maximum system throughput of  
10 such process sequencing is mainly by robot swap speed and the number of swaps each robot needs to complete full sequencing.

Conventionally, the system architectures for depositing Cu barrier and seed layers on semiconductor wafers  
15 have 3 or 4 wafers swaps for buffer robot and 3 swaps for transfer robot. For the configuration having 3 swaps each for buffer robot and transfer robot, the robot-limited system throughput is much higher than the one with 4 swaps for buffer robot. However, problems occur when maximum allowed  
20 chamber time become too short to complete the process required.

Therefore, the prior art is deficient in the lack of an effective system or means for depositing Cu barrier and seed  
25 layers on semiconductor wafers with ultra high system throughput while the chamber time is sufficient for performing the processes. The present invention fulfills this long-standing need and desire in the art.

## SUMMARY OF THE INVENTION

In one aspect of the present invention, there is  
5 provided a system architecture of semiconductor  
manufacturing equipment, wherein degas chamber(s) are  
integrated to the conventional pass-through chamber location.

In another aspect of the present invention, there is  
10 provided a system for depositing Cu barrier and seed layers on  
a semiconductor wafer. This system comprises a front opening  
unified pod(s), a single wafer loadlock chamber(s), a degas  
chamber(s), a preclean chamber(s), a Ta or TaN process  
chamber(s), and a Cu process chamber(s). The degas chamber  
15 is integrated to a pass-through chamber location.

In still another aspect of the present invention,  
there is provided is a method of depositing Cu barrier and seed  
layers on a semiconductor wafer using the above-described  
20 system. This method comprises the steps of (1) loading the  
wafer to the degas chamber from the front opening unified pod  
through the single wafer loadlock chamber; (2) performing  
degas processing on the wafer in the degas chamber; (3)  
removing native oxide from the wafer surface in the preclean  
25 chamber; (4) depositing Ta or TaN on the wafer in the Ta or  
TaN process chamber; (5) passing the processed wafer through  
the degas chamber; (6) depositing Cu seed layer on the wafer in  
the Cu process chamber; and (7) transferring the processed

wafer from the Cu process chamber to the front opening unified pod through the single wafer loadlock chamber, thereby obtaining a wafer with Cu barrier and seed layer deposition.

5           Other and further aspects, features, and advantages of the present invention will be apparent from the following description of the embodiments of the invention given for the purpose of disclosure.

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#### **BRIEF DESCRIPTION OF THE DRAWINGS**

So that the matter in which the above-recited  
15 features, advantages and objects of the invention, as well as others which will become clear, are attained and can be understood in detail, more particular descriptions of the invention briefly summarized above may be had by reference to certain embodiments thereof which are illustrated in the  
20 appended drawings. These drawings form a part of the specification. It is to be noted, however, that the appended drawings illustrate embodiments of the invention and therefore are not to be considered limiting in their scope.

25           **Figures 1A and 1B** show conventional system architectures for Cu barrier and seed layer deposition. The abbreviations used herein are: FOUP - front opening unified pod; SWLL - single wafer loadlock chamber; DG - degas

chamber; SWLL/DG - single wafer loadlock degas chamber; PC - preclean chamber; P/T - pass-through chamber; Ta(N) - Ta or TaN process chamber; Cu - Cu process chamber.

5                **Figure 2** shows system architecture of Cu barrier and seed layer deposition system in accordance with the present invention. The same abbreviations are used herein as those in Figures 1A and 1B.

## 10                **DETAILED DESCRIPTION OF THE INVENTION**

15                Provided herein is a novel system architecture with a unique degas chamber location to substantially improve the system throughput and reduce cost of the conventional design of semiconductor manufacturing system.

20                Examples of the conventional system architecture to deposit Cu barrier and seed layers on semiconductor wafers are illustrated in Figures 1A and 1B. In these systems, typical wafer process sequences are:

                  FOUN → SWLL → DG → PC → P/T → Ta(N) → Cu → P/T  
25                → SWLL → FOUN (Figure 1A); or  
                  FOUN → SWLL/DG → P/T → PC → Ta(N) → P/T → Cu  
                  → SWLL → FOUN (Figure 1B).

In case of Figure 1A, the buffer robot has 4 wafer swaps (SWLL, DG, PC, and P/T) and transfer robot has 3 swaps {P/T, Ta(N), and Cu} to complete the entire wafer processes through the system. So, if the system has buffer and transfer robots with the same swap time, the buffer robot will limit theoretical robot-limited system throughput. Reducing 1 swap of buffer robot can be done by performing degas process (DG) in single wafer loadlock (SWLL) chamber. Figure 1B show the system architecture with integrated degas module in single wafer loadlock chamber. In this case, both buffer and transfer robots have 3 swaps each.

Table 1 shows robot-limited system throughput and maximum allowed chamber time per given throughput with changes in number of swaps and swap times. Since number of swaps is one less with Figure 1B configuration compared with Figure 1A case, theoretical robot-limited system throughput of Figure 1B configuration is much higher.

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**TABLE 1**

System Throughput and Chamber Time with Various Number of Swaps and Swap Times

	Wafer swap time (sec)	14	12	10
Configuration Figure 1A	# of Robots	2	2	2
	# of Swaps (per robot)	4	4	4
	Throughput (wph)	64	75	90
	Chamber time (sec)	98	84	70
Configuration Figure 1B	# of Robots	2	2	2
	# of Swaps (per robot)	3	3	3
	Throughput (wph)	86	100	120
	Chamber time (sec)	70	60	50

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One potential problem with Figure 1B configuration is that maximum allowed chamber time to maintain maximum system throughput may become too short to perform the process required. For example, it is achievable to maintain system throughput of 120 wph with the wafer swap time of 10 sec, if chamber time is less than 50 sec. However, sometimes it is very difficult to reduce overall chamber time. Single wafer loadlock degas (SWLL/DG) chamber is a potential throughput limiting factor which may need longer chamber time than

maximum allowed chamber time. Since SWLL chamber deals with pumpdown/vent processes (typically  $\geq 25\text{sec}$ ), degas process time (typical  $\geq 30\text{sec}$ .) will be very limited with SWLL/DG chamber configuration.

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Another potential problem with Figure 1B configuration is the case of employing a resistive heater style degas in SWLL/DG. Since SWLL/DG chamber needs to be vented to 1 atmospheric pressure to return fully processed wafer to the front opening unified pod, the wafer gets heat from the heated pedestal and the wafer temperature elevates while venting the chamber. In this case, when the door is open to transfer the wafer from SWLL/DG chamber to the front opening unified pod, oxygen entering into the chamber can easily form oxide on Cu film and may also cause particle generation by forming oxide on the heated pedestal. To prevent oxygen from entering the SWLL/DG chamber, a high flow of nitrogen or argon ( $>10$  standard liters per minute) may be needed while the door is open to the atmosphere.

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Provided herein is a new system to solve the above-mentioned problems. In the new system, the wafer process sequence is:

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FOUP  $\rightarrow$  SWLL  $\rightarrow$  DG  $\rightarrow$  PC  $\rightarrow$  Ta(N)  $\rightarrow$  DG (as a P/T)  $\rightarrow$  Cu  $\rightarrow$  SWLL  $\rightarrow$  FOUP (Figure 2).



In one aspect, this new system provides a solution of simpler system architecture to maintain the same system throughput without sacrificing degas process time by integrating degas module to the conventional pass-through (P/T) chamber position. Both robots still maintain 3 swaps each, i.e., the buffer robot has SWLL, Cu, DG; while the transfer robot has DG, PC, Ta(N). With such configuration, new degas chamber has a fully dedicated chamber time for degas process. The new system architecture easily enables system to achieve ultra high system throughput of > 100 wph. In addition to system configurations for Cu barrier and seed layer deposition, this new configuration may be beneficial for some other applications (mostly 3 swap cases) as well.

In another aspect, this new system provides a cost reduction compared to the cost of the conventional systems shown in Figures 1A and 1B. By replacing dedicated pass-through chambers with degas chambers, cost will be greatly reduced for materials, system building, and system maintenance.

The new degas chamber of the presently disclosed new system may use the designs which are well-known in the state of the art, such as IR lamps degas (orienter/degas chamber of 200 mm Endura CL), resistively heated pedestal degas (degas chamber of 300 mm Endura CL), IR lamps degas with cooldown pedestal (SWLL/degas chambers of 200 mm/300 mm Endura SL), or resistively heated pedestal degas with

integrated cooldown station (anneal chamber of 200 mm/300 mm ECP).

In conclusion, provided herein is a system  
5 architecture of semiconductor manufacturing equipment, wherein degas chamber(s) are integrated to the conventional pass-through chamber location. Specifically, the system has 3 swaps each for buffer robot and transfer robot.

10 Also provided herein is a system for depositing Cu barrier and seed layers on a semiconductor wafer. This system comprises a front opening unified pod(s) to carry pre- or post-processed wafers, a single wafer loadlock chamber(s), a degas chamber(s), a preclean chamber(s), a Ta or TaN process  
15 chamber(s), and a Cu process chamber(s). The degas chamber is integrated to a pass-through chamber. That is, the pass-through chamber in conventional designs is replaced by the degas chamber. Examples of degas chamber include IR lamps degas chamber, resistively heated pedestal degas chamber, IR  
20 lamps degas chamber with cool-down pedestal, or resistively heated pedestal degas chamber with integrated cool-down station.

Still provided herein is a method of depositing Cu  
25 barrier and seed layers on a semiconductor wafer using the above-described system. This method comprises the steps of (1) loading the wafer to the degas chamber from the front opening unified pod through the single wafer loadlock

chamber; (2) performing degas processing on the wafer in the degas chamber; (3) removing (etching) native oxide from the wafer surface in the preclean chamber; (4) depositing Ta or TaN (as a Cu barrier layer) on the wafer in the Ta or TaN process chamber; (5) passing the processed wafer through the degas chamber; (6) depositing Cu seed layer on the wafer in the Cu process chamber; and (7) transferring the processed wafer from the Cu process chamber to the front opening unified pod through the single wafer loadlock chamber, thereby obtaining a wafer with Cu barrier and seed layer deposition. This method provides ultra high system throughput of more than 100 wafers per hour.

Any patents or publications mentioned in this specification are indicative of the levels of those skilled in the art to which the invention pertains. These patents and publications are herein incorporated by reference to the same extent as if each individual publication was specifically and individually indicated to be incorporated by reference.

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One skilled in the art will readily appreciate that the present invention is well adapted to carry out the objects and obtain the ends and advantages mentioned, as well as those inherent therein. It will be apparent to those skilled in the art that various modifications and variations can be made in practicing the present invention without departing from the spirit or scope of the invention. Changes therein and other uses will occur to those skilled in the art which are

encompassed within the spirit of the invention as defined by  
the scope of the claims.